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RESEARCH MEMORANDUM

SOME EFFECTS OF LEADING-EDGE ROUGHNESS ON THE AILERON EFFECTIVENESS AND DRAG OF A THIN RECTANGULAR WING EMPLOYING A FULL-SPAN PLAIN AILERON AT MACH NUMBERS FROM 0.6 TO 1.5

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RESEARCH MEMORANDUM

SOME EFFECTS OF LEADING-EDGE ROUGHNESS ON THE AILERON EFFECTIVENESS AND DRAG OF A THIN RECTANGULAR WING EMPLOYING A FULL-SPAN PLAIN AILERON AT MACH NUMBERS FROM 0.6 TO 1.5

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SUMMARY

In order to determine some effects of fixing transition on aileron effectiveness and drag, the Langley Pilotless Aircraft Research Division has made a limited investigation of the effects of adding leading-edge roughness to the surfaces of an unswept, untapered, 6-percent-thick, circular-arc-airfoil wing equipped with a full-span, 0.2-chord, plain, trailing-edge aileron. The tests were made by means of rocket-propelled models in free flight over a Mach number range from 0.6 to 1.5.

The results of the tests indicate that the addition of roughness reduces the rolling effectiveness at subsonic speeds. Adding roughness had little effect on rolling effectiveness in the supersonic range. The drag coefficient was higher for the wing with roughness than for the smooth wing over the entire test Mach number range. The increase in drag coefficient with the addition of roughness was higher for the wing with a series of ridges than for the wing with a solid projection except in the transonic region.

INTRODUCTION

In order to determine some effects of fixing transition on aileron effectiveness and drag, the Langley Pilotless Aircraft Research Division has made a limited investigation of the effects of adding leading-edge roughness to the surfaces of an unswept, untapered wing. The investigation was made using rocket-propelled test models in free flight. Tests were made on a wing with smooth surfaces and with two types of roughness strips located near the leading edge. The wing had a 6-percent-thick circular-arc airfoil section and a full-span, 0.2-chord plain sealed trailing-edge aileron deflected 5°.

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SYMBOLS

A	aspect ratio, b^2/S, 3.7
b	diameter of circle swept by wing tips, ft
c	wing chord, ft
C_D	drag coefficient based on exposed area of three wings, 1.563 ft ^{2}
C_L	model lift coefficient, $\frac{\text{Model lift}}{qS}$
C_{L_α}	variation of model lift coefficient with angle of attack, per degree, $\partial C_L/\partial\alpha$
C_{L_δ}	variation of model lift coefficient with flap deflection, per degree, $\partial C_L/\partial\delta$
M	Mach number
p	rolling velocity, radians/sec
q	dynamic pressure, lb/sq ft
R	Reynolds number based on wing chord, 0.590 ft
S	total area of two wings to model center line, sq ft
V	model flight-path velocity, ft/sec
$pb/2V$	wing-tip helix angle, radians
α	angle of attack, deg
δ	deflection of each flap, deg

DESCRIPTION OF MODELS AND TESTS

The geometry and dimensions of a typical test model are shown in the photograph presented as figure 1 and the sketch presented as figure 2. A close-up view of a wing with roughness strip is presented in figure 3. Models 1 and 2 had smooth wing surfaces. Models 3, 4, 5, and 6 had a series of ridges on both upper and lower surfaces from 0.01c to 0.08c

along the entire span. The ridges were 0.004 inch (0.00057c) high on models 3, 4, and 5 and 0.002 inch (0.00028c) high on model 6. Model 7 had a solid projection 0.002 inch high and 0.125 inch wide on both upper and lower surfaces located with the forward edge of the projection at 0.05c. All models had 6-percent-thick, circular-arc-airfoil sections and aspect ratios of 3.7, were unswept and untapered, and were equipped with full-span, 0.2-chord plain sealed trailing-edge ailerons. Each aileron was deflected 5°. A section view of the wing is shown together with enlarged sketches of the forward sections of the wings with roughness strips in figure 4. All model bodies were bodies of revolution, the coordinates of which are given in reference 1.

The models were propelled to a maximum Mach number of 1.5 by a two-stage rocket propulsion system. During a period of free flight following burnout of the second propulsion stage, flight-path velocity, rolling velocity, range, and altitude were recorded continuously by radar and spinsonde radio equipment. These data were used with atmospheric data collected by radiosonde to calculate the variation of rolling-effectiveness parameter $pb/2V$ and drag coefficient C_D with Mach number. The variation of test Reynolds numbers with Mach number is shown in figure 5.

A complete description of the test technique is given in references 1 and 2.

ACCURACY

From previous experience it is estimated that the accuracy of the test data is within the following limits:

	Subsonic	Supersonic
$pb/2V$	± 0.003	± 0.002
C_D	± 0.003	± 0.002
M	± 0.01	± 0.01

The $pb/2V$ values have not been corrected for inertia effects. For this reason, the limits of the accuracy of $pb/2V$ are somewhat larger in the transonic region.

RESULTS AND DISCUSSION

The variation of the rolling-effectiveness parameter $pb/2V$ with Mach number is presented for all models in figure 6. The method of reference 3 was used to correct $pb/2V$ values for the small amount of built-in wing incidence resulting from construction tolerances.

Rolling-effectiveness data for the various configurations used in this investigation are summarized in figure 7. In cases where more than one model of a given configuration were flown, the $pb/2V$ values were averaged to give a single curve for the configuration. It may be seen from figure 7 that rolling effectiveness was higher for the smooth wing than for the wing with either type of roughness strip in the subsonic range. The wing with solid roughness strips had higher rolling effectiveness than those with a series of ridges. At supersonic speeds the addition of roughness had little effect on rolling effectiveness.

In tests on a similar wing (ref. 4) the addition of roughness was found to decrease the flap-effectiveness factor C_{L_δ} in the subsonic range. No C_{L_α} values were given in reference 4 for the wing with roughness strips. However, previous subsonic tests show that C_{L_α} is not appreciably affected by the addition of roughness (data from ref. 5 are typical). Since $pb/2V$ is proportional to the ratio of C_{L_δ} to C_{L_α}, the data from references 4 and 5 indicate a reduction in rolling effectiveness at subsonic speeds when roughness is added to the wing.

Figure 8 presents the variation of the drag coefficient C_D with Mach number for the four configurations tested in the present investigation. As in the case of $pb/2V$, drag coefficients for the various models of a given configuration were averaged to give a single curve for the configuration. As might be expected, the drag coefficient is higher for the wing with either type of roughness strip than for the smooth wing. The increase in drag with the addition of roughness is slightly higher for the wings with a series of ridges than for the wing with a solid projection except in the transonic region. Changing the height of the ridges from 0.00028c to 0.00057c apparently had little effect on drag.

The slight increase in drag coefficient near $M = 1.0$ for the wing with 0.00028c ridges over that of the other wings with roughness is unexplained. However, it is believed that this does not affect the other test results for this wing.

CONCLUSIONS

The results of an investigation of some effects of leading-edge roughness on the rolling effectiveness and drag of an unswept, untapered, 6-percent-thick wing equipped with a full-span, 0.2-chord plain trailing-edge aileron indicate the following:

1. The addition of roughness near the leading edge resulted in reduced rolling effectiveness at subsonic speeds; there was no appreciable effect of roughness on rolling effectiveness in the supersonic range.

2. Subsonic rolling effectiveness was lower for the wing with roughness strips formed by a series of ridges than for the wing with solid projections of half the height of the ridges.

3. Drag coefficient was higher for the wing with either type of roughness strip than for the smooth wing over the entire test Mach number range.

4. The increase in drag due to the addition of roughness was higher for the wings with ridges than for the wing with a solid projection except in the transonic region; changing the height of the ridges had little effect on drag.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., September 9, 1953.

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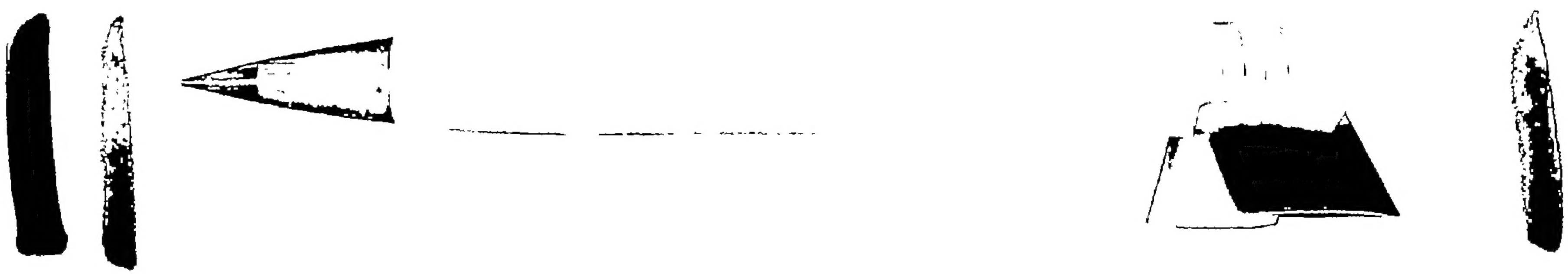

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Figure 1.- Typical model having roughness strip.

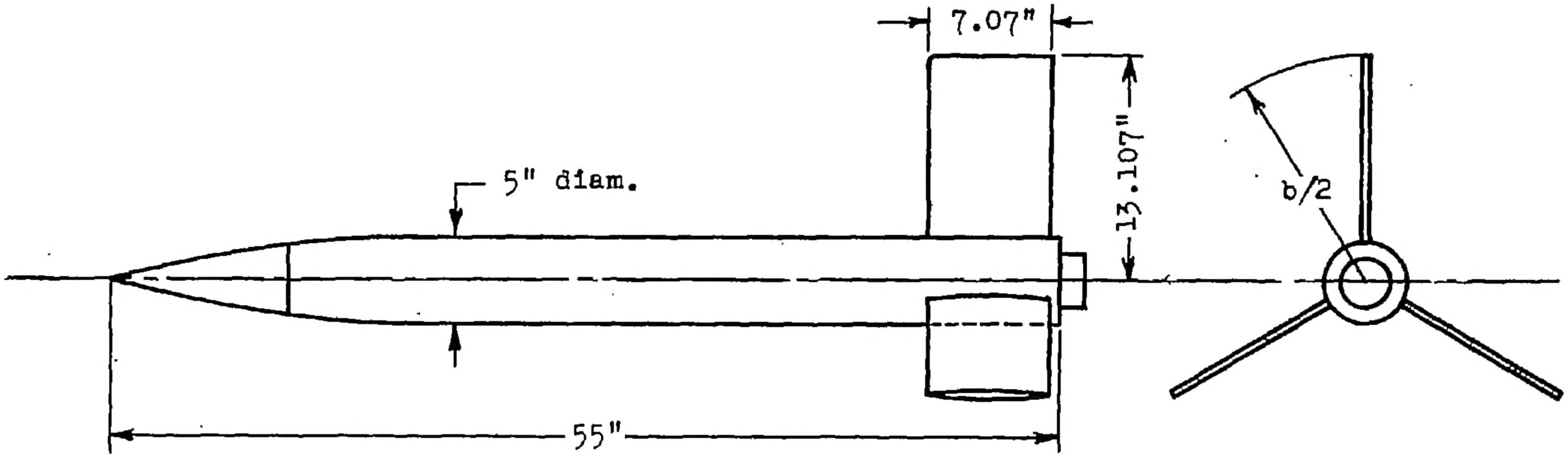

Figure 2.- Sketch of typical model.

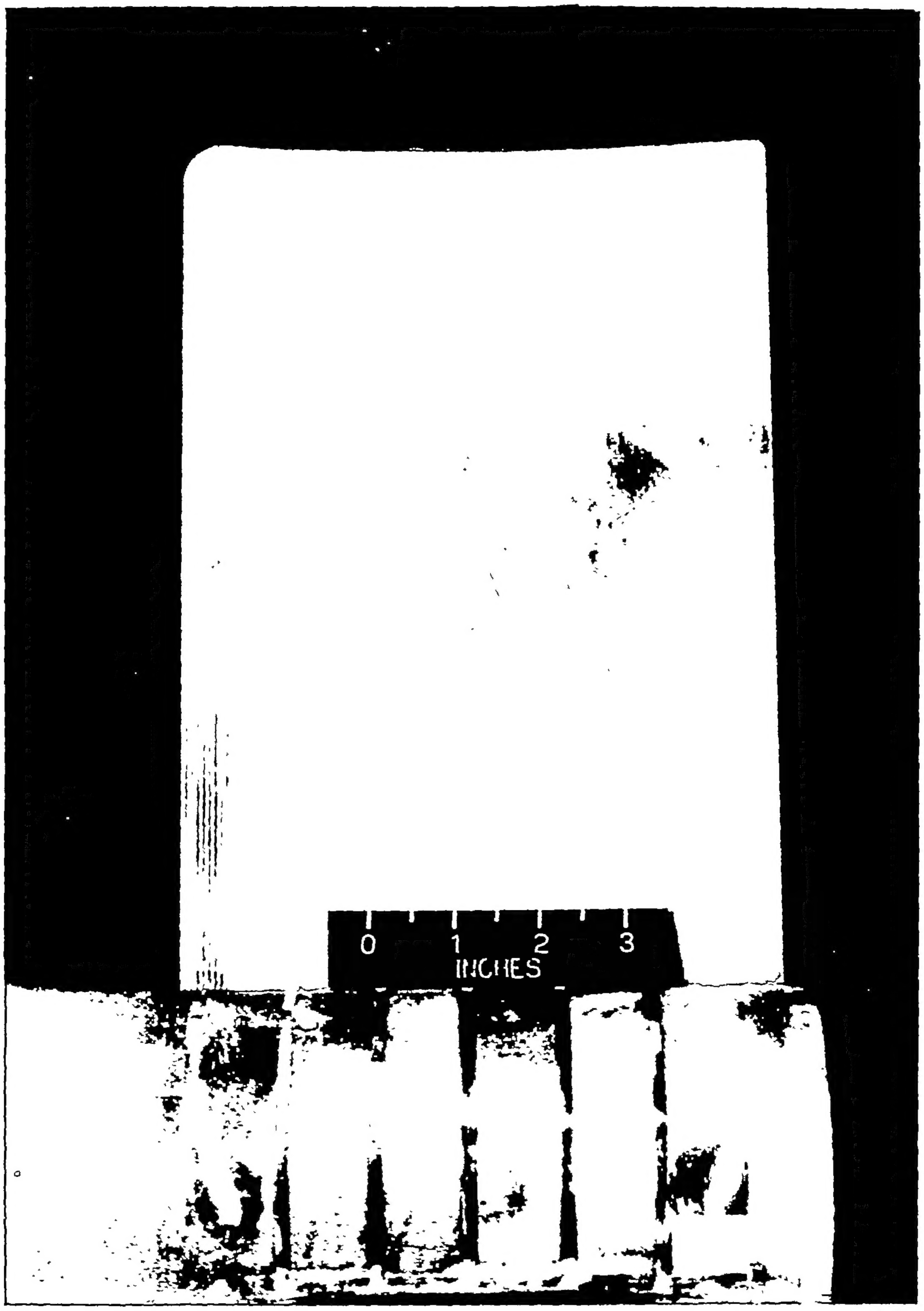

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Figure 3.- Close-up view of wing with roughness strip.

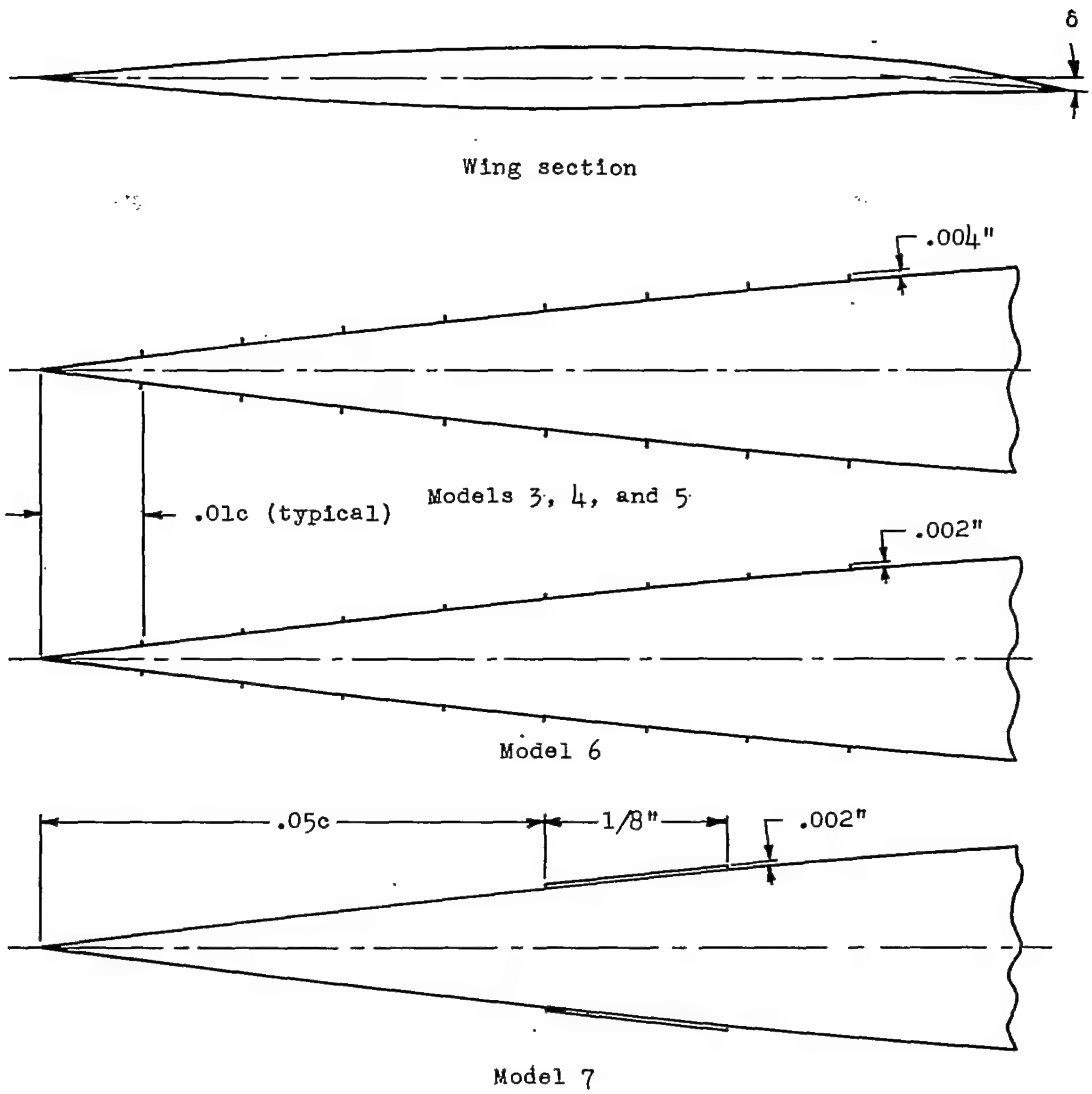


Figure 4.- Wing section together with enlarged forward sections of wings with roughness. Wing section is full scale, enlarged sections are 10 times full scale.

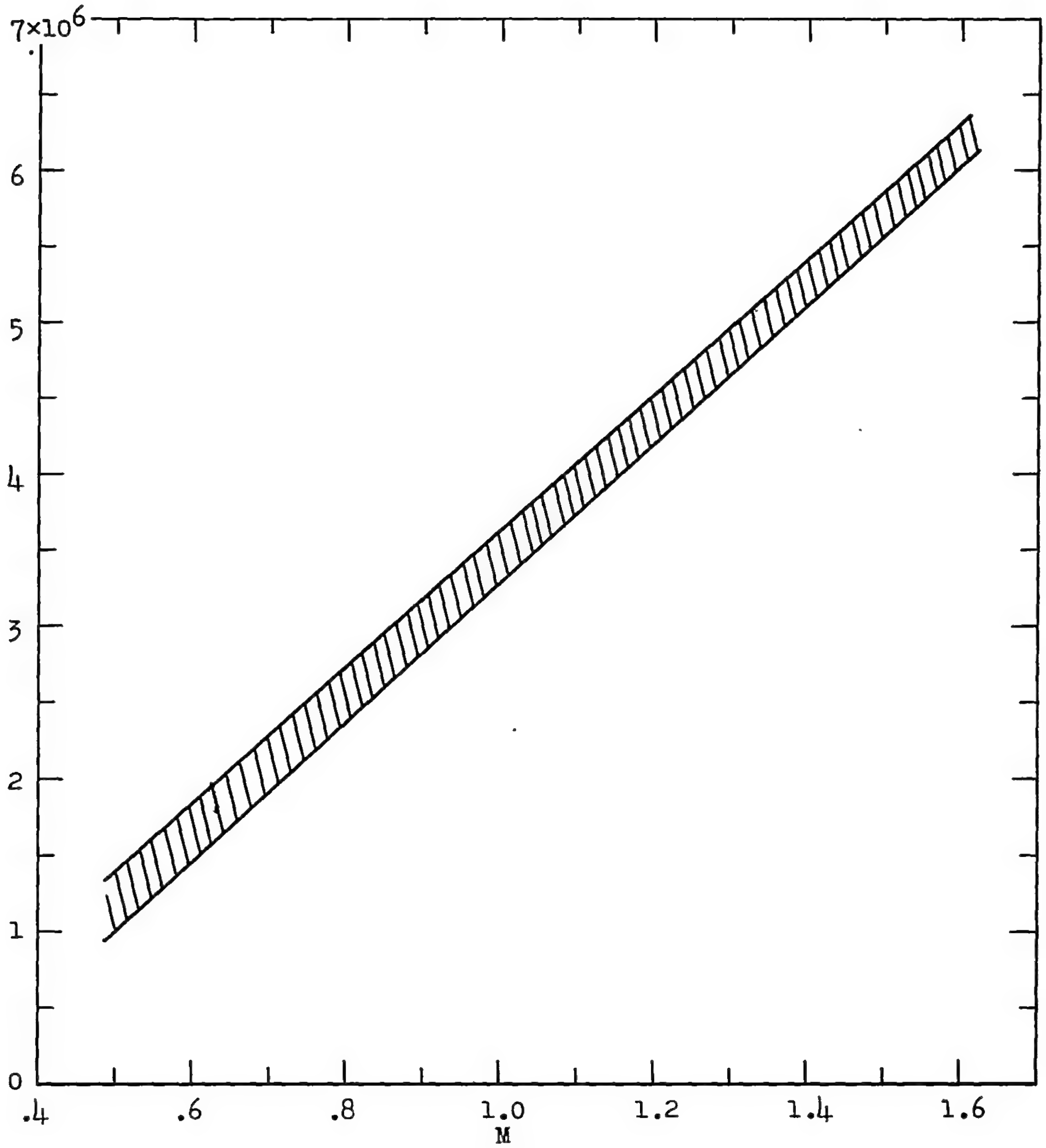
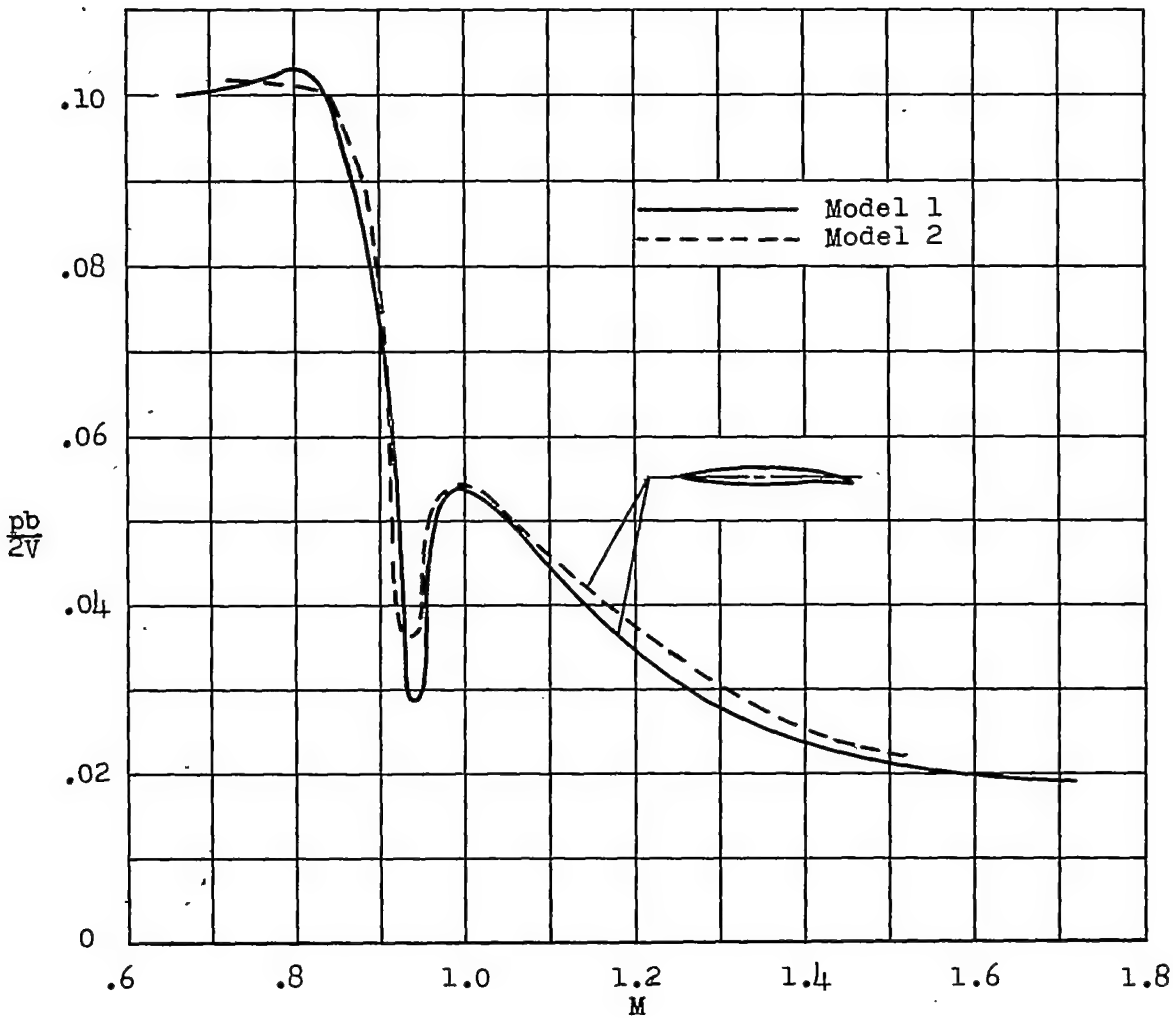
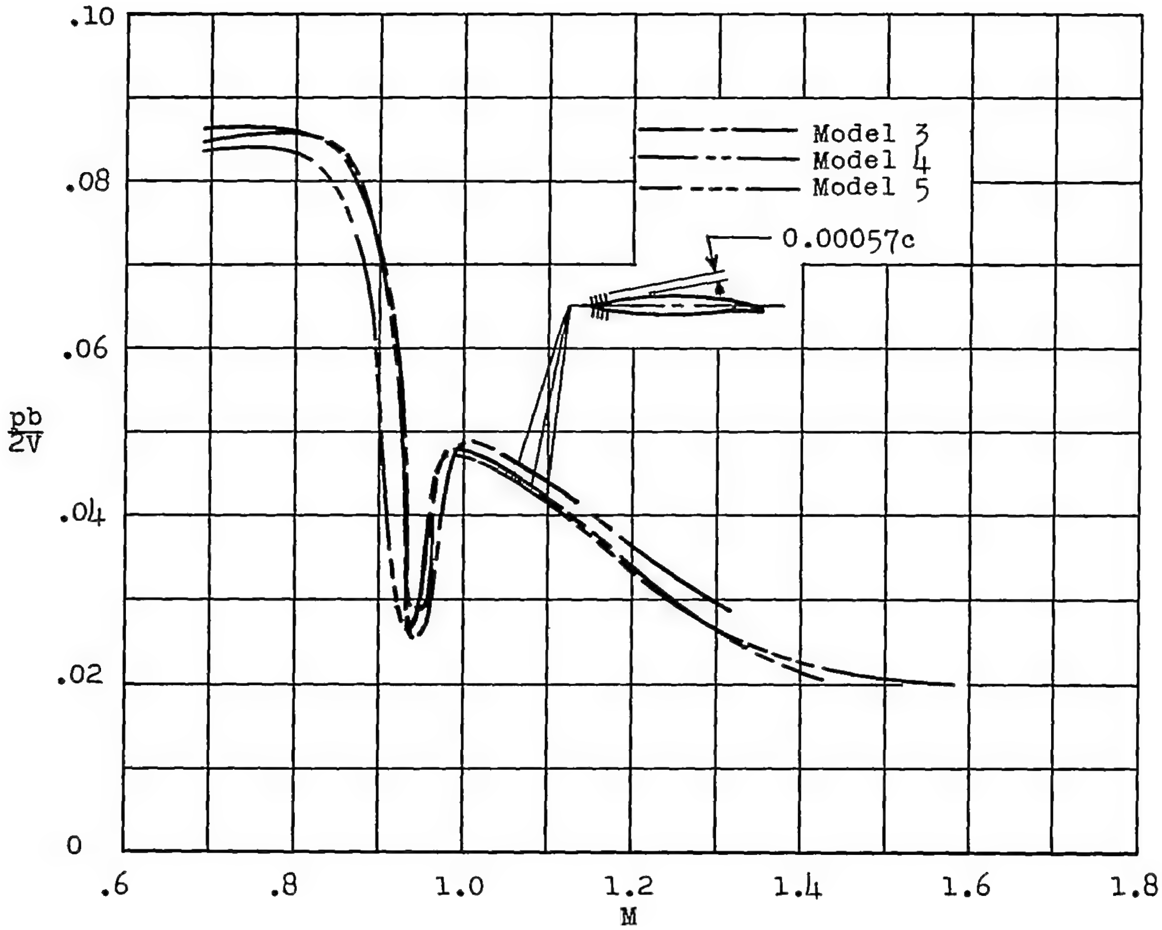


Figure 5.- Range of test Reynolds numbers as a function of Mach number. Reynolds numbers based on wing chord, 0.590 foot.



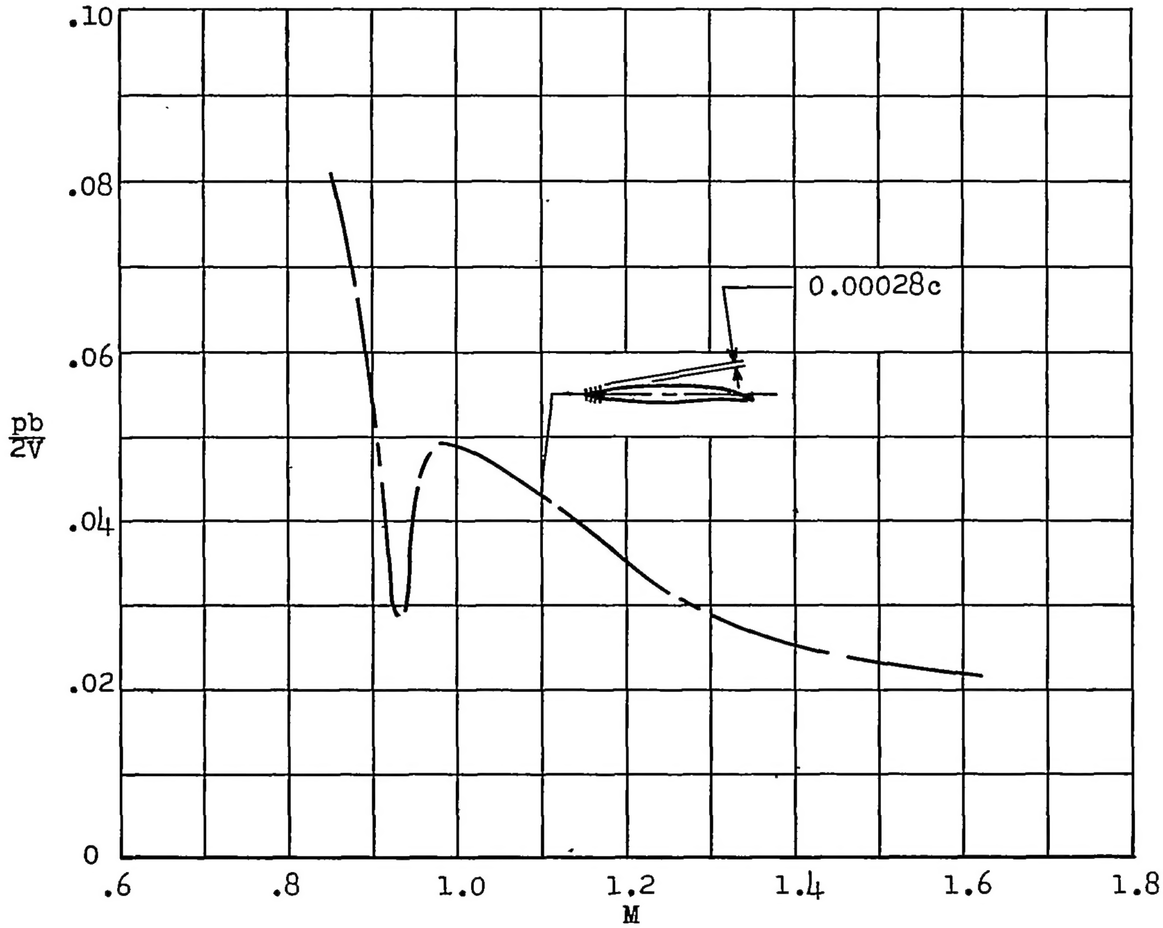
(a) Models 1 and 2.

Figure 6.- Variation of rolling effectiveness parameter pb/2V with Mach number. Height of roughness on sketches is exaggerated. $\delta = 5^{\circ}$.



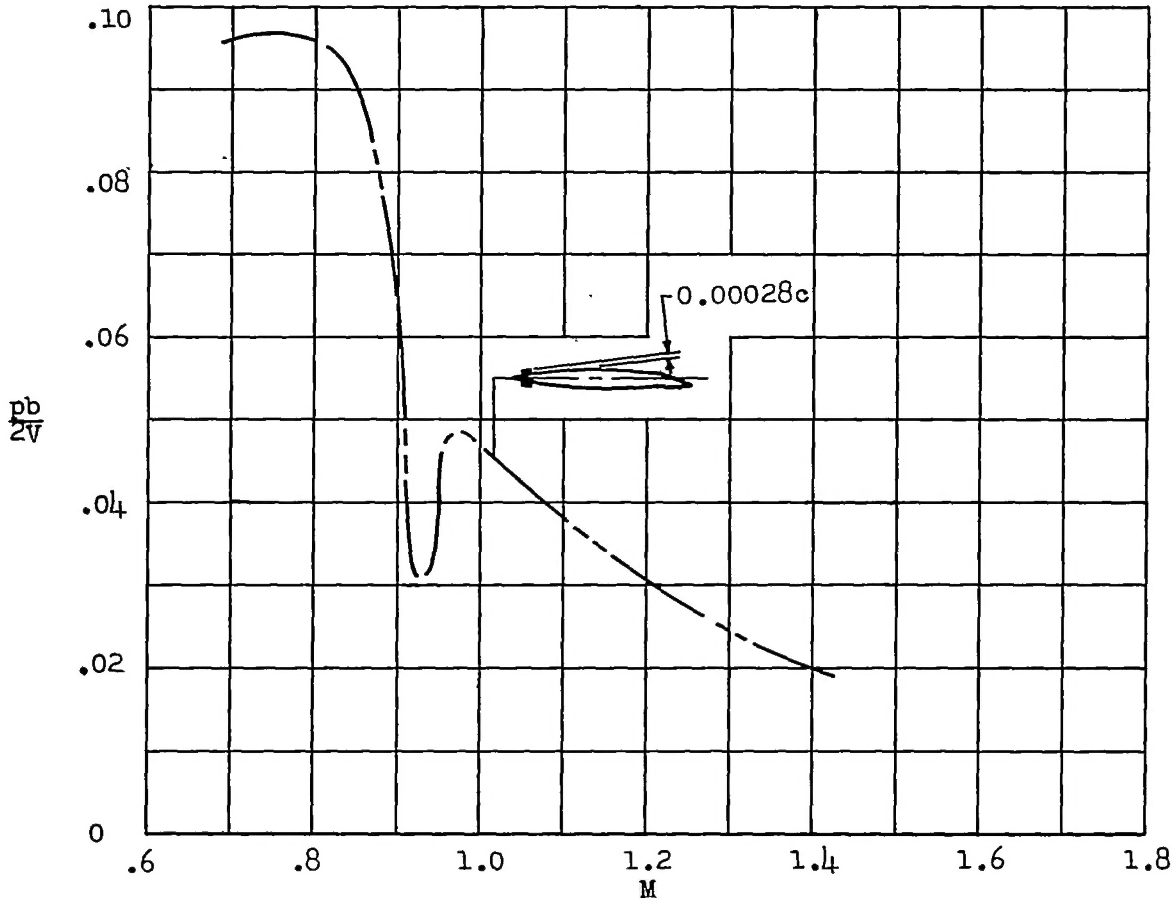
(b) Models 3, 4, and 5.

Figure 6.- Continued.



(c) Model 6.

Figure 6.- Continued.



(d) Model 7.

Figure 6.- Concluded.

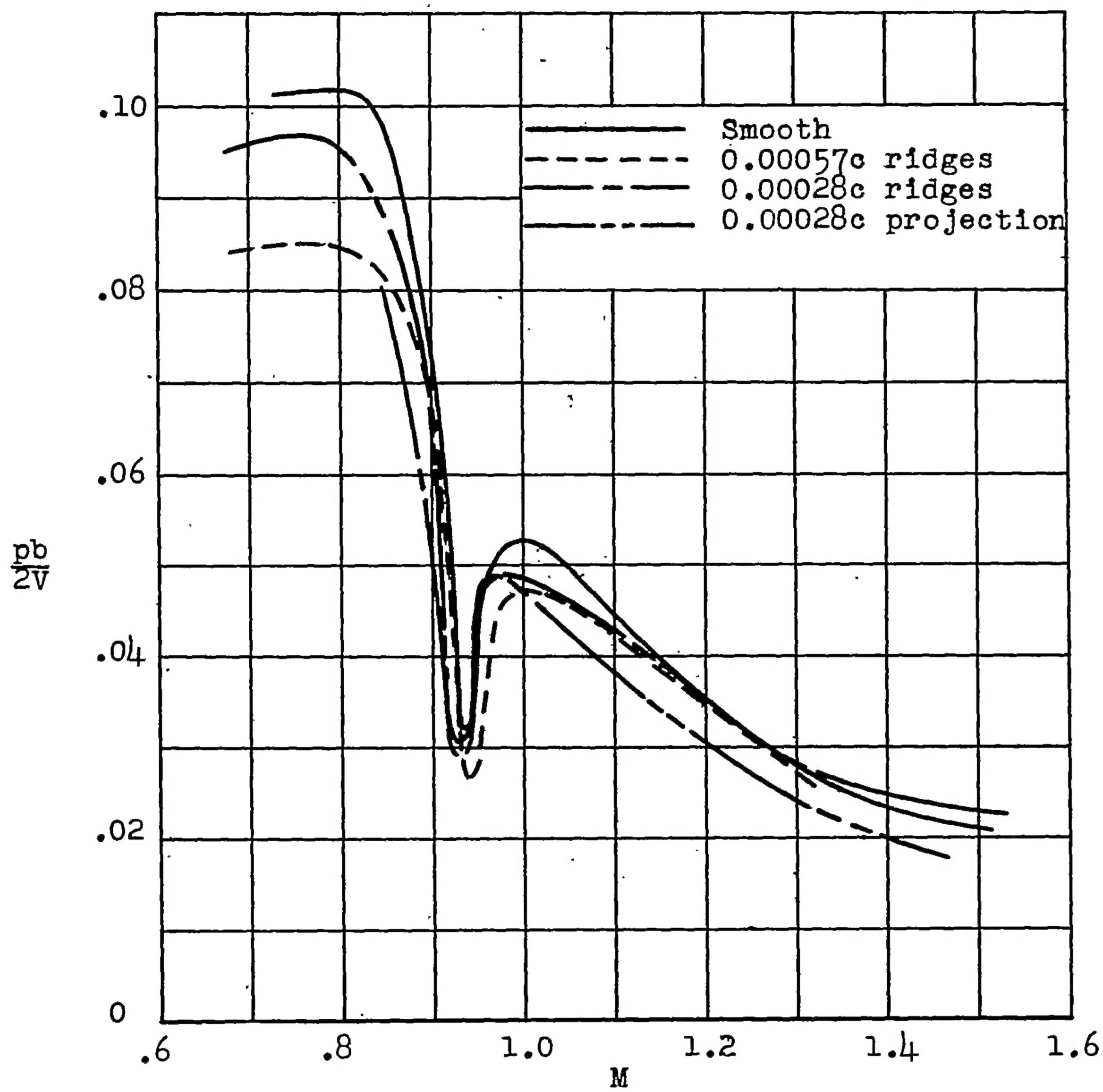


Figure 7.- Comparison of rolling effectiveness for the various configurations. $\delta = 5^{\circ}$.

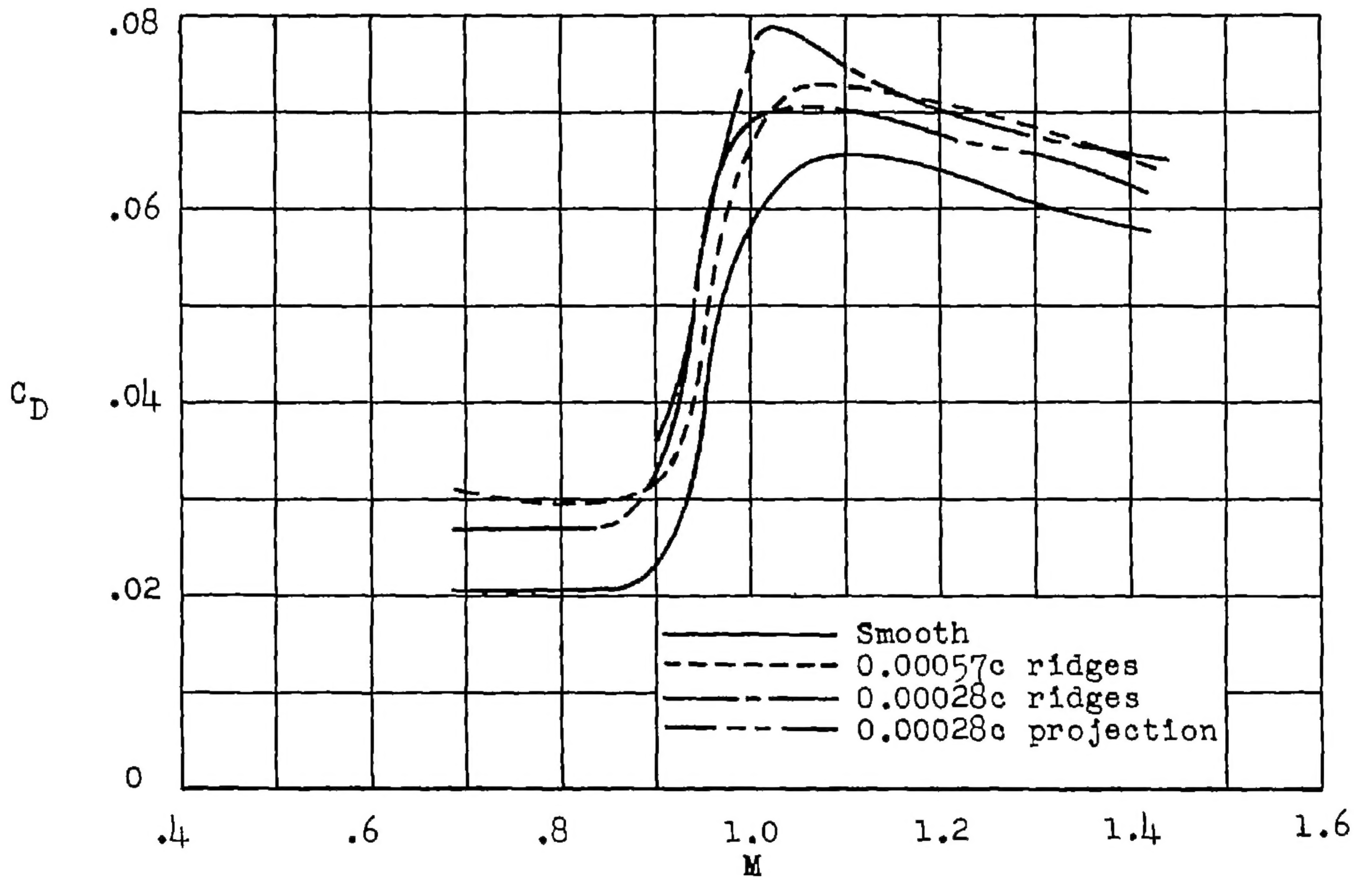


Figure 8.- Variation of drag coefficient C_D with Mach number.